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Non-Monotonic Trends in Adolescent Psychological and Somatic Complaints: A 28-Year Analysis across 41 Countries (1994–2022)

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Abstract

The research investigated monotonic and non-monotonic temporal patterns in adolescents' psychological and somatic symptoms, including variations by gender. Analyses were conducted on repeated cross-sectional data from the Health Behaviour in School-aged Children (HBSC) survey spanning 1994–2022, involving 15-year-old adolescents from 41 nations (N = 470,797). Three polynomial logistic regression approaches (linear, quadratic, cubic) were evaluated for optimal fit, with stratified examinations by gender and symptom type.

Temporal patterns differed according to gender and symptom category. Rising trends appeared in 82.3% of instances (linear in 25%, U-shaped quadratic in 28.7%, cubic in 28.7%), whereas 14% lacked a distinct pattern, and 3.7% declined. Males predominantly exhibited linear rises or stable patterns, while females more commonly displayed cubic or U-shaped trajectories. Psychological symptoms frequently followed U-shaped or cubic trajectories, in contrast to somatic symptoms, which primarily demonstrated linear rises.Across nations, adolescents' psychological and somatic symptoms exhibited varied temporal trajectories, with non-monotonic forms (U-shaped and cubic) commonly occurring beside linear rises. Such results underscore the intricate nature of national-level shifts across three decades, indicating that sole reliance on linear models may inadequately represent this variability.

Keywords: Adolescence, Mental health, Gender differences, Cross-national, HBSC

Introduction

Optimal health and well-being form the foundation for essential developmental milestones during adolescence [1], where mental health plays a central role. Yet, over one-third of adolescents frequently report various psychological and somatic symptoms [2, 3]. These symptoms act as key markers of challenges in mental health and overall well-being, often representing stress responses to psychosocial pressures in young people's lives without evident physical origins [4, 5]. Furthermore, such symptoms can adversely impact adolescents' broader health, daily functioning, and sense of well-being, with potential progression to mental disorders in adulthood [6] that substantially add to the worldwide burden of disease [7]. Emerging data point to a rise in these symptoms across time [8], potentially linked to country-specific occurrences and broader crises such as the 2008 financial downturn and the COVID-19 pandemic, alongside growing awareness of mental health and expanded access to related services. Extended longitudinal trend examinations are vital for comprehending these shifts and informing strategies to track and enhance adolescent well-being.

The HBSC survey, conducted every four years across multiple nations, offers a valuable resource for tracking temporal changes in adolescent health and well-being via the HBSC Multiple Health Complaints scale. First developed in 1986, the scale was updated in 1994 to include eight items assessing somatic (headache, backache, stomachache, dizziness) and psychological

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(feeling nervous, feeling low, irritability, sleep difficulties) symptoms, and it has stayed consistent since [9]. Somatic and psychological symptoms frequently co-occur [10–13], leading some investigators to combine them into a single psychosomatic factor [13, 14], while others distinguish them as separate psychological and somatic dimensions [11, 12, 15, 16]. Both frameworks have strong empirical support and have been applied in prior adolescent health investigations.

Research adopting the single-factor perspective has identified comparable temporal patterns in psychosomatic symptoms across various settings. For example, psychosomatic complaints remained largely steady through the 1990s and early 2000s in nations like Scotland, England, and the Netherlands [17–19]. From around 2010, however, rises in adolescents experiencing multiple psychosomatic symptoms emerged [17–20]. These patterns have been corroborated in aggregated international datasets [8].

Investigations using the two-factor framework have uncovered heterogeneous temporal shifts in psychological and somatic symptoms across contexts. Psychological symptoms generally remained stable in the 1990s and early 2000s, with subsequent increases varying by country after the early 2000s. Switzerland, for instance, displayed stability from 1994 to 2006 [15], whereas Norway showed an upward pattern in that timeframe followed by a decline in 2014 [16]. More contemporary analyses in Czechia (2002–2018), Italy (2010–2018), and Canada (2014–2022, especially girls) documented rises in psychological symptoms [20–22]. One multinational analysis indicated stability in psychological symptoms from 2002 to 2010, then growth through 2018 [23], while another using combined data (2002–2018) found increases in psychological symptoms in most countries [24]. Regarding somatic symptoms, upward trends from the 1990s to early 2000s were observed in Switzerland, Norway, and Czechia [15, 16, 21], succeeded by declines in Norway (2010–2014) and Czechia (2010–2018) [16, 21]. In contrast, Italy and Canada evidenced increases during those years [20, 22]. A single cross-national examination to date has verified rising somatic symptoms from 2002 to 2018 [23]. In light of these inconsistent trajectories for psychological and somatic symptoms, coupled with limited long-span investigations, there is a need to integrate findings within a unified analysis and assess psychological and somatic symptoms separately (two-factor approach) over a prolonged period and across multiple nations to better clarify variations in temporal patterns.

Previous investigations have predominantly adopted a monotonic perspective, focusing on linear shifts in psychosomatic symptoms across time. Nevertheless, such a method might fail to fully reflect the intricate nature of these trajectories [25]. The occurrence of non-monotonic temporal patterns, including quadratic (U-shaped or inverted U-shaped) or cubic forms, has seldom been explored, with only one prior investigation addressing this [25]. These non-linear trajectories are frequently overlooked, despite their relevance, particularly in analyses covering extended periods where several fluctuations could arise. The present research seeks to enhance comprehension of these shifts across a prolonged timeframe and incorporate the latest representative multinational data through application of the two-factor framework.

While varying temporal patterns have emerged, certain findings remain uniform regarding prevalence and gender distinctions. Investigations applying the two-factor model have consistently indicated lower rates of somatic relative to psychological symptoms [15, 16, 20, 21, 26]. Additionally, elevated prevalence of health symptoms—whether assessed via single- or two-factor methods—has been observed among girls compared with boys [15–21, 26, 27]. Deeper exploration of gender- and dimension-specific prevalence variations within trend analyses that account for diverse trajectory types could yield a more refined perspective on these temporal developments.

This study

The studies reviewed above underscore the requirement for additional examination of varied temporal trajectories beyond the standard linear framework. Accordingly, to bridge these shortcomings, the current investigation intends to guide policymaking and identify priority populations for customized initiatives, such as meeting the distinct requirements of males and females in managing different aspects of health symptoms across time. Furthermore, leveraging representative samples from adolescents in 41 nations, this work seeks to reveal possible international variations, stressing the value of incorporating diverse cultural and contextual elements together with gender disparities and differences by symptom category. To achieve greater insight into these extended temporal patterns, the analysis covers nearly three decades across 41 countries. This study evaluates

which trajectory type (linear, quadratic, or cubic) best represents the observed variations over the last three decades in adolescents' psychological and somatic symptoms for each nation individually. It also investigates whether these varying temporal trajectories differ between males and females.

Materials and Methods

Study design and sample

The multinational HBSC survey gathers information on health and well-being among 11-, 13-, and 15-year-old adolescents every four years. In each participating region or country, a representative school-based sample is obtained in accordance with the standardised international protocol [9]. The current analysis utilised data from eight survey waves (1994, 1998, 2002, 2006, 2010, 2014, 2018, and 2022), encompassing three decades. The sample comprised 41 countries, accounting for 79% of the 52 nations in the full dataset. Inclusion required countries to have at least four data points, regardless of consecutiveness, to satisfy the minimum for cubic trend assessment. Prior systematic evidence has established that 15-year-olds exhibit the highest prevalence rates, greatest gender disparities, and broadest international differences [8, 20, 22, 24]; thus, only this age cohort was retained. The resulting sample consisted of 470,797 15-year-old adolescents.

Measures

Psychological and somatic symptoms in adolescents were assessed via the HBSC Multiple Health Complaints scale [9]. Participants reported the frequency over the preceding six months of eight symptoms: feeling low, irritability or bad temper, feeling nervous, difficulties in getting to sleep, headache, backache, stomachache, and feeling dizzy. Responses ranged from 1 ("about every day") to 5 ("rarely or never"). A two-dimensional structure was applied, with the initial four items representing psychological symptoms and the subsequent four denoting somatic symptoms [11, 15, 16]. Both scales were binarised using the threshold of two or more symptoms occurring more than once a week [11, 15, 16, 20]. This threshold was selected for its applicability to both categories, as a stricter criterion of three or more would yield low somatic prevalence, while a looser one of one or more would produce excessively high psychological prevalence. The instrument has demonstrated strong internal consistency and construct validity [12], along with configural and metric invariance across nations [13]. Gender was ascertained by asking whether participants identify as a boy or a girl. Age was derived from the reported month and year of birth.

Statistical analyses

Prevalence estimates for psychological and somatic symptoms were computed by country, survey wave, and gender. To identify the best-fitting temporal trajectory within each country, logistic regression was performed separately for males and females, and for each symptom category, yielding 164 distinct analyses (k = 164; 41 countries × 2 genders × 2 symptom dimensions). The survey wave variable (collection year) was centred, and orthogonal polynomials were incorporated for quadratic and cubic terms. Three models—cubic, quadratic, and linear—were compared, fitted via the "glmnet" package in R version 4.1-1 [28]. The preferred trajectory was selected according to improvement in fit and model significance, applying a stringent threshold ($p < .001$) to account for large sample sizes [29]. Two supplementary sensitivity checks were then undertaken. The first used aggregated data to examine how alternative thresholds (at least one, two, or three symptoms more than weekly) affected trajectory outcomes. The second evaluated potential COVID-19 effects on overall patterns by re-estimating models excluding 2022 data and contrasting them with complete models. Sensitivity assessments were not feasible for Russia, Ukraine, and the United States owing to missing 2022 data.

Results and Discussion

Descriptives

Figure 1 displays the recorded prevalence trajectories by nation. Furthermore, **Figure 2** depicts the range between maximum and minimum prevalence across the observation period per nation, revealing substantial inter-country variability over time. In general, peak prevalence for both somatic and psychological symptoms occurred in 2022 in the majority of nations for males (32 countries) and females (36 countries). In contrast, the timing of minimum prevalence showed considerable cross-national diversity. Specifically, for psychological symptoms, the lowest rates within countries appeared at various intervals from 1994 to 2014. For somatic symptoms, minima within countries spanned 1994 to 2018. Notably, in 1994—when data were available from 20 countries—somatic symptom prevalence reached its

lowest for females in 17 countries and males in 13 countries relative to subsequent waves.

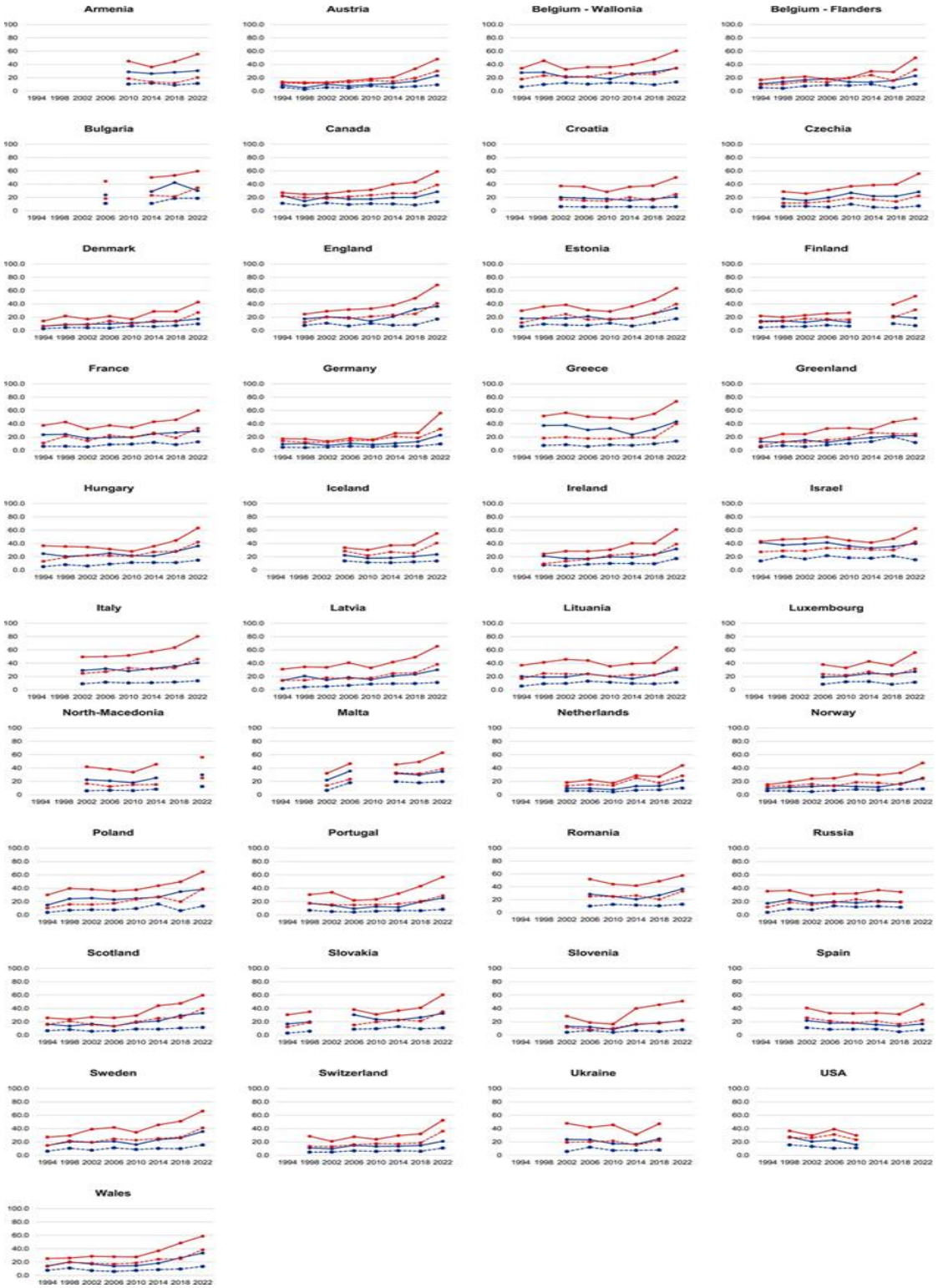
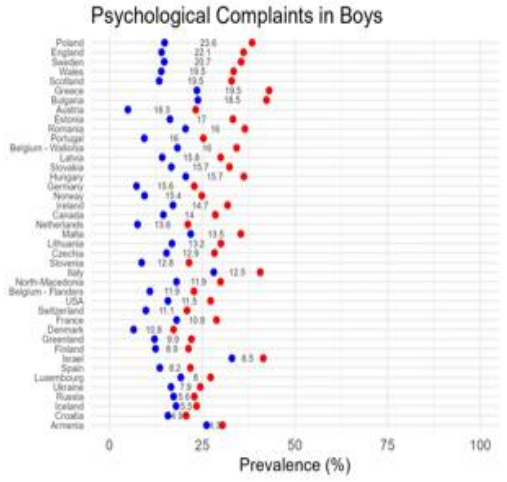


Figure 1. Prevalence of two or more psychological and somatic symptoms among males and females by nation and survey year (Health Behaviour in School-aged Children study, 1994–2022 across 41 countries).

Notes. Solid lines denote psychological symptom prevalence; dotted lines denote somatic symptom prevalence. Blue lines indicate males; red lines indicate females.



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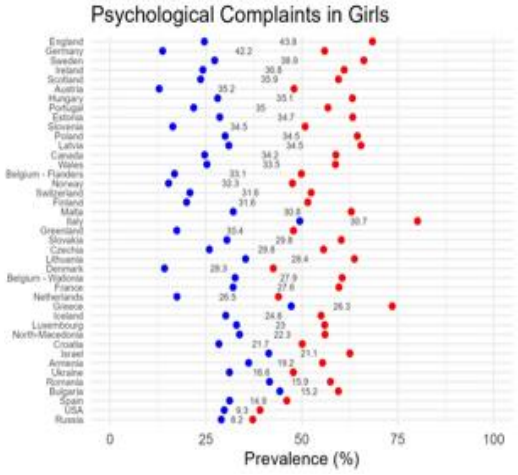

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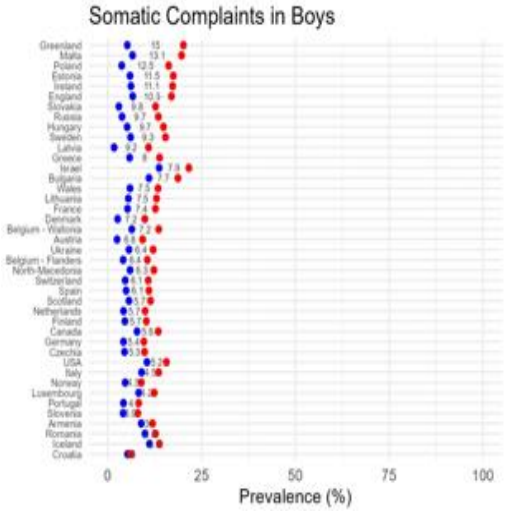

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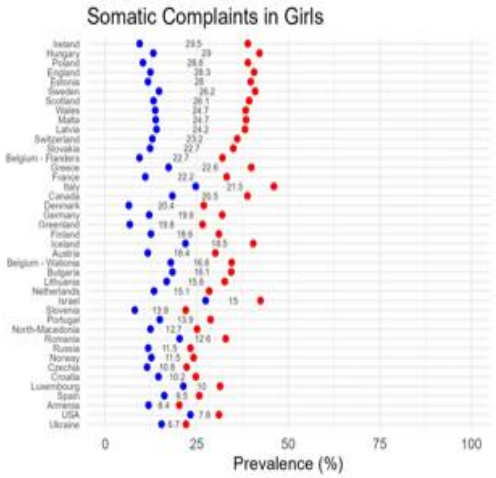

d)

Figure 2. Dumbbell plot illustrating maximum and minimum prevalence of two or more psychological and somatic symptoms by gender and nation across all countries (Health Behaviour in School-aged Children study, 1994–2022 across 41 countries). Notes. Grey segments between dumbbells represent the difference between the highest and lowest prevalence.

Nationally, psychological symptom prevalence typically exceeded somatic rates, varying from 4.9% (males, Austria, 1998) to 80.2% (females, Italy, 2022). Somatic symptom prevalence ranged from 1.7% (males, Latvia, 1994) to 16.1% (females, Italy, 2022). Elevated rates for both symptom types were particularly evident in Italy and Israel. Greece exhibited notably high psychological symptom prevalence. Moreover, temporal variability (gap between extremes) was generally greater for psychological than somatic symptoms in both genders, indicating more pronounced fluctuations in psychological symptoms. Across all nations, females consistently reported higher psychological and somatic symptom levels than males.

Trend patterns

Substantial multinational variation emerged in temporal trajectories for both symptom categories and genders **(Tables 1 and 2)**. In the majority of instances across countries, genders, and symptom types, 82.3% (k = 135) of trajectories showed rising prevalence over the study

duration. Three distinct upward patterns were identified: linear (25%; k = 41; consistent rise from baseline), quadratic U-shaped (28.7%; k = 47; initial decline succeeded by recent rise), and cubic (28.7%; k = 47; repeated fluctuations culminating in recent increase). Declining trajectories appeared in a minority (3.7%, k = 6). Specifically, linear declines occurred in 1.8% (k = 3), reflecting a steady reduction, while inverted U-shaped quadratic patterns (initial rise followed by decline) also accounted for 1.8% (k = 3). Stability (no discernible pattern) characterised 14% (k = 23) of cases **(Table 3)**.

Table 1. Temporal trajectory for psychological symptoms by nation and gender (Health Behaviour in School-aged Children study, 1994–2022 across 41 countries).

Country	Boys: Cubic coefficient (SE)	Boys: Quadratic coefficient (SE)	Boys: Linear coefficient (SE)	Girls: Cubic coefficient (SE)	Girls: Quadratic coefficient (SE)	Girls: Linear coefficient (SE)	Trend form (Girls)	Trend form (Boys)
Armenia	−0.195 (0.451)	0.471 (0.451)	0.002 (0.003)	−0.751 (0.494)	2.311 (0.494)***	0.010 (0.002)***	QU	—
Austria	0.529 (0.319)	2.242 (0.319)***	0.005 (0.000)***	1.306 (0.409)**	5.032 (0.409)***	0.013 (0.001)***	QU	QU
Belgium – Flanders	2.120 (0.371)***	0.803 (0.372)*	0.003 (0.000)***	2.453 (0.436)***	4.273 (0.437)***	0.011 (0.001)***	C	C
Belgium – Wallonia	0.006 (0.436)	2.990 (0.436)***	0.002 (0.001)***	1.711 (0.486)***	3.860 (0.486)***	0.008 (0.001)***	C	QU
Bulgaria	−2.541 (0.458)***	−1.231 (0.460)**	0.007 (0.001)***	0.254 (0.498)	0.513 (0.497)	0.009 (0.002)***	LI	C
Canada	0.311 (0.399)	2.950 (0.399)***	0.002 (0.000)***	0.692 (0.471)	5.240 (0.471)***	0.011 (0.000)***	QU	QU
Croatia	0.440 (0.386)	0.998 (0.386)*	−0.000 (0.001)	0.437 (0.479)	3.646 (0.479)***	0.006 (0.001)***	QU	—
Czechia	0.770 (0.419)	0.370 (0.419)	0.004 (0.001)***	1.566 (0.481)**	2.855 (0.481)***	0.012 (0.001)***	QU	LI
Denmark	0.273 (0.313)	0.326 (0.313)	0.003 (0.000)***	1.470 (0.419)***	2.504 (0.419)***	0.008 (0.001)***	C	LI
England	0.916 (0.410)*	2.318 (0.410)***	0.006 (0.001)***	1.970 (0.463)***	3.503 (0.464)***	0.015 (0.001)***	C	QU
Estonia	1.398 (0.410)***	2.099 (0.411)***	0.005 (0.001)***	3.140 (0.475)***	4.390 (0.477)***	0.009 (0.001)***	C	C
Finland	−0.095 (0.357)	0.863 (0.357)**	0.002 (0.001)***	0.660 (0.439)	2.830 (0.439)***	0.010 (0.001)***	QU	LI
France	−0.635 (0.418)	2.106 (0.419)***	0.003 (0.001)***	1.022 (0.486)*	4.284 (0.486)***	0.007 (0.001)***	QU	QU
Germany	1.104 (0.319)***	2.199 (0.320)***	0.004 (0.000)***	2.738 (0.411)***	6.287 (0.412)***	0.012 (0.001)***	C	C
Greece	2.001 (0.473)***	3.299 (0.473)***	0.001 (0.001)	2.966 (0.486)***	4.636 (0.488)***	0.007 (0.001)***	C	C

Greenland	−0.213 (0.366)	0.350 (0.365)	0.004 (0.001)***	0.631 (0.457)	0.236 (0.457)	0.010 (0.001)***	LI	LI
Hungary	0.929 (0.432)*	2.337 (0.433)***	0.003 (0.001)***	2.486 (0.476)***	6.123 (0.477)***	0.008 (0.001)***	C	QU
Iceland	−0.464 (0.400)	1.593 (0.400)***	0.002 (0.001)*	0.510 (0.479)	3.206 (0.479)***	0.014 (0.001)***	QU	QU
Ireland	0.212 (0.405)	1.997 (0.405)***	0.003 (0.001)***	1.072 (0.467)*	2.655 (0.467)***	0.013 (0.001)***	QU	QU
Israel	1.161 (0.485)*	1.161 (0.485)**	−0.001 (0.001)	3.994 (0.495)***	3.078 (0.497)***	0.005 (0.001)***	C	—
Italy	0.302 (0.469)	1.256 (0.469)**	0.006 (0.001)***	0.766 (0.481)	2.857 (0.481)***	0.014 (0.001)***	QU	LI
Latvia	0.938 (0.403)*	1.675 (0.403)***	0.005 (0.001)***	2.360 (0.481)***	3.837 (0.482)***	0.010 (0.001)***	C	QU
Lithuania	1.550 (0.410)***	1.485 (0.410)***	0.002 (0.001)***	4.635 (0.489)***	2.998 (0.492)***	0.005 (0.001)***	C	C
Luxembourg	0.156 (0.419)	0.065 (0.419)	0.005 (0.001)***	0.884 (0.487)	2.436 (0.488)***	0.010 (0.001)***	QU	LI
North Macedonia	−0.597 (0.421)	1.274 (0.421)**	0.005 (0.001)***	−0.976 (0.490)*	2.505 (0.490)***	0.008 (0.001)***	QU	LI
Malta	1.284 (0.459)**	−0.433 (0.460)	0.004 (0.002)**	1.514 (0.489)**	0.768 (0.490)	0.013 (0.002)***	LI	—
Netherlands	0.181 (0.326)	1.402 (0.326)***	0.005 (0.001)***	0.930 (0.432)*	2.221 (0.433)***	0.011 (0.001)***	QU	QU
Norway	1.253 (0.336)***	1.005 (0.336)**	0.004 (0.001)***	1.260 (0.430)**	0.743 (0.431)	0.009 (0.001)***	LI	C
Poland	1.655 (0.437)***	0.859 (0.437)*	0.007 (0.001)***	2.613 (0.485)***	3.432 (0.485)***	0.010 (0.001)***	C	C
Portugal	0.001 (0.364)	2.708 (0.364)***	0.004 (0.001)***	0.406 (0.462)	5.750 (0.462)***	0.011 (0.001)***	QU	QU
Romania	0.457 (0.449)	2.698 (0.449)***	0.006 (0.001)***	−0.317 (0.497)	3.586 (0.497)***	0.005 (0.001)***	QU	QU
Russia	0.289 (0.394)	−0.014 (0.394)	0.000 (0.001)	−0.862 (0.470)	1.455 (0.470)**	0.000 (0.001)	—	—
Scotland	−0.238 (0.392)	2.487 (0.392)***	0.006 (0.001)***	−0.323 (0.460)	4.142 (0.460)***	0.012 (0.001)***	QU	QU
Slovakia	1.815 (0.431)***	0.187 (0.432)	0.004 (0.001)***	2.722 (0.479)***	3.555 (0.480)***	0.008 (0.001)***	C	C
Slovenia	−0.719 (0.356)*	1.328 (0.357)***	0.005 (0.001)***	−3.616 (0.457)***	2.746 (0.460)***	0.018 (0.001)***	C	QU
Spain	0.233 (0.377)	0.759 (0.377)*	−0.003 (0.001)***	0.392 (0.475)	3.419 (0.475)***	0.001 (0.001)	QU	LD
Sweden	1.562 (0.410)***	1.982 (0.411)***	0.005 (0.001)***	2.273 (0.484)***	2.329 (0.485)***	0.011 (0.001)***	C	C
Switzerland	0.791 (0.348)*	0.814 (0.348)*	0.003 (0.001)***	1.543 (0.455)***	4.959 (0.455)***	0.009 (0.001)***	C	LI

Ukraine	1.235 (0.408)**	1.726 (0.408)***	−0.001 (0.001)	1.937 (0.493)***	2.033 (0.494)***	−0.003 (0.001)*	C	QU
USA	−1.045 (0.407)*	0.019 (0.407)	−0.008 (0.002)***	−2.103 (0.471)***	−0.150 (0.472)	−0.003 (0.002)	C	LD
Wales	1.192 (0.432)**	3.682 (0.432)***	0.007 (0.000)***	0.632 (0.480)	4.918 (0.479)***	0.014 (0.001)***	QU	QU

Notes. Estimates (Standard error); P < 0.001 = *; P < 0.01 = ; P < 0.05 = *; LI, linear increase; LD, linear decrease; QU, quadratic U-shaped; QIU, quadratic inverted U-shaped; C, cubic.

Table 2. Temporal trajectory for somatic symptoms by nation and gender (Health Behaviour in School-aged Children study, 1994–2022 across 41 countries).

Country	**Boys: Cubic (SE)**	**Boys: Quadratic (SE)**	**Boys: Linear (SE)**	**Girls: Cubic (SE)**	**Girls: Quadratic (SE)**	**Girls: Linear (SE)**	**Trend (Girls)**	**Trend (Boys)**
Armenia	0.464 (0.305)	0.224 (0.305)	0.000 (0.002)	0.393 (0.363)	1.671 (0.363)***	0.001 (0.002)	QU	—
Austria	−0.214 (0.241)	0.494 (0.241)*	0.001 (0.000)***	1.098 (0.375)**	2.488 (0.375)***	0.006 (0.000)***	QU	LI
Belgium – Flanders	0.328 (0.271)	−0.362 (0.271)	0.002 (0.000)***	1.140 (0.386)**	1.354 (0.386)***	0.007 (0.000)***	QU	LI
Belgium – Wallonia	0.800 (0.311)**	−0.517 (0.311)	0.002 (0.000)**	1.205 (0.430)**	0.802 (0.430)	0.005 (0.001)***	LI	—
Bulgaria	−0.993 (0.349)**	0.634 (0.349)	0.005 (0.001)***	1.407 (0.419)***	1.247 (0.419)**	0.007 (0.001)***	C	LI
Canada	0.386 (0.304)	0.646 (0.304)*	0.001 (0.000)	0.847 (0.432)	3.376 (0.432)***	0.005 (0.000)***	QU	—
Croatia	0.003 (0.234)	0.116 (0.234)	0.000 (0.001)	0.364 (0.381)	1.339 (0.381)***	0.003 (0.001)***	QU	—
Czechia	0.640 (0.243)**	0.224 (0.243)	0.000 (0.000)	1.453 (0.370)***	0.544 (0.370)	0.004 (0.001)***	C	—
Denmark	0.210 (0.225)	0.413 (0.225)	0.002 (0.000)***	1.362 (0.332)***	1.443 (0.333)***	0.006 (0.000)***	C	LI
England	1.075 (0.293)***	1.027 (0.293)***	0.002 (0.001)***	1.915 (0.405)***	1.458 (0.406)***	0.009 (0.001)***	C	C
Estonia	1.039 (0.299)***	0.991 (0.300)**	0.003 (0.000)***	3.144 (0.406)***	2.279 (0.408)***	0.007 (0.001)***	C	C
Finland	−0.115 (0.250)	−0.188 (0.250)	0.001 (0.000)**	1.471 (0.378)***	1.090 (0.378)**	0.005 (0.001)***	C	—
France	−0.240 (0.281)	0.063 (0.281)	0.002 (0.000)***	1.527 (0.403)***	0.420 (0.403)	0.005 (0.001)***	C	LI
Germany	0.342 (0.238)	0.391 (0.238)	0.002 (0.000)***	0.614 (0.380)	2.359 (0.380)***	0.006 (0.001)***	QU	LI

Greece	0.352 (0.287)	0.989 (0.287)***	0.002 (0.000)***	2.375 (0.415)***	3.825 (0.416)***	0.008 (0.001)***	C	QU
Greenland	−0.508 (0.296)	−0.051 (0.297)	0.004 (0.001)***	−0.260 (0.375)	−0.312 (0.375)	0.007 (0.001)***	LI	LI
Hungary	0.091 (0.294)	0.073 (0.294)	0.003 (0.000)***	2.104 (0.422)***	1.751 (0.422)***	0.008 (0.001)***	C	LI
Iceland	−0.215 (0.328)	0.826 (0.328)*	0.000 (0.001)	0.346 (0.446)	3.267 (0.446)***	0.008 (0.001)***	QU	—
Ireland	0.537 (0.295)	0.630 (0.295)*	0.003 (0.001)***	1.016 (0.398)*	0.787 (0.398)*	0.010 (0.001)***	LI	LI
Israel	−0.131 (0.384)	−1.453 (0.384)***	3.835 (0.000)	2.291 (0.468)***	1.582 (0.469)***	0.004 (0.001)***	C	QIU
Italy	0.387 (0.315)	0.216 (0.315)	0.002 (0.001)*	1.469 (0.464)**	1.067 (0.465)*	0.009 (0.001)***	LI	—
Latvia	0.063 (0.264)	−0.325 (0.264)	0.003 (0.000)***	1.030 (0.407)*	2.419 (0.407)***	0.008 (0.001)***	QU	LI
Lithuania	0.753 (0.298)*	−1.001 (0.298)***	0.001 (0.000)**	2.530 (0.421)***	0.680 (0.422)	0.003 (0.001)***	C	QIU
Luxembourg	0.848 (0.304)**	−0.355 (0.304)	0.001 (0.001)	0.768 (0.433)	0.944 (0.433)*	0.004 (0.001)**	—	—
North Macedonia	0.054 (0.269)	0.486 (0.269)	0.003 (0.001)***	−0.277 (0.372)	1.666 (0.372)***	0.005 (0.001)***	LI	LI
Malta	0.761 (0.368)*	−0.845 (0.369)*	0.005 (0.001)***	0.660 (0.446)	−0.482 (0.447)	0.011 (0.001)***	LI	LI
Netherlands	−0.044 (0.249)	0.644 (0.249)*	0.002 (0.001)***	0.348 (0.390)	0.567 (0.390)	0.006 (0.001)***	LI	LI
Norway	−0.287 (0.248)	0.261 (0.248)	0.001 (0.000)**	0.478 (0.364)	0.398 (0.364)	0.003 (0.001)***	LI	—
Poland	0.202 (0.282)	−0.441 (0.282)	0.003 (0.000)***	1.654 (0.404)***	1.520 (0.404)***	0.008 (0.001)***	C	LI
Portugal	−0.212 (0.241)	0.548 (0.241)*	0.001 (0.000)*	0.531 (0.389)	2.420 (0.389)***	0.005 (0.001)***	QU	—
Romania	0.662 (0.321)*	0.016 (0.321)	0.001 (0.001)	1.542 (0.441)***	1.691 (0.442)***	0.004 (0.001)***	C	—
Russia	−0.193 (0.303)	−1.171 (0.303)***	0.003 (0.001)***	−0.461 (0.384)	−1.039 (0.384)**	0.003 (0.001)***	LI	QIU
Scotland	−0.103 (0.275)	0.473 (0.275)	0.002 (0.000)***	0.701 (0.403)	3.095 (0.403)***	0.006 (0.001)***	QU	LI
Slovakia	−0.119 (0.288)	−0.828 (0.288)**	0.003 (0.000)***	1.061 (0.405)**	1.656 (0.405)***	0.007 (0.001)***	QU	LI
Slovenia	0.410 (0.237)	0.252 (0.237)	0.001 (0.001)*	−0.843 (0.354)**	0.912 (0.355)**	0.007 (0.001)***	LI	LI
Spain	−0.063 (0.278)	0.136 (0.278)	−0.002 (0.001)**	−0.178 (0.406)	1.299 (0.406)**	−0.002 (0.001)***	LI	—
Sweden	0.904 (0.299)**	0.436 (0.299)	0.002 (0.000)***	2.007 (0.427)***	1.442 (0.428)***	0.006 (0.001)***	C	LI

Switzerland	0.624 (0.248)**	0.492 (0.248)*	0.002 (0.000)***	2.231 (0.388)***	2.913 (0.389)***	0.007 (0.001)***	C	LI
Ukraine	1.025 (0.272)***	−0.477 (0.272)	0.000 (0.001)	1.170 (0.398)**	0.344 (0.399)	0.000 (0.001)	—	C
USA	0.218 (0.331)	0.385 (0.331)	−0.004 (0.001)**	−1.140 (0.440)**	−0.901 (0.441)*	−0.002 (0.002)	—	—
Wales	0.649 (0.309)*	1.622 (0.309)***	0.002 (0.000)***	2.401 (0.443)***	3.797 (0.444)***	0.009 (0.000)***	C	QU

Notes. Estimates (Standard error); P < 0.001 = *; P < 0.01 = ; P < 0.05 = *; LI, linear increase; LD, linear decrease; QU, quadratic U-shaped; QIU, quadratic inverted U-shaped; C = cubic.

Table 3. Summary of temporal trajectories for psychological and somatic symptoms by gender and nation for 1994–2018 and 1994–2022 (Health Behaviour in School-aged Children study, 41 countries).

Country/region	Trend until 2018: Psychological (Girls)	Trend until 2018: Psychological (Boys)	Trend until 2018: Somatic (Girls)	Trend until 2018: Somatic (Boys)	Trend until 2022: Psychological (Girls)	Trend until 2022: Psychological (Boys)	Trend until 2022: Somatic (Girls)	Trend until 2022: Somatic (Boys)
Armenia e	—	—	Linear decrease	—	Quadratic—U-shaped*	—	Quadratic—U-shaped*	—
Austria a	Quadratic—U-shaped	Linear increase	Linear increase	—	Quadratic—U-shaped	Quadratic—U-shaped*	Quadratic—U-shaped*	Linear increase*
Belgium – Flanders a	Linear increase	—	Cubic	Quadratic—inverted U-shaped	Cubic*	Cubic*	Quadratic—U-shaped*	Linear increase*
Belgium – Wallonia a	Quadratic—U-shaped	Quadratic—U-shaped	Linear increase	Quadratic—inverted U-shaped	Cubic*	Quadratic—U-shaped	Linear increase	—*
Bulgaria d	Linear increase	Quadratic—U-shaped	—	Quadratic—U-shaped	Linear increase	Cubic*	Cubic*	Linear increase*
Canada a	Quadratic—U-shaped	—	Linear increase	—	Quadratic—U-shaped	Quadratic—U-shaped*	Quadratic—U-shaped*	—
Croatia c	Quadratic—U-shaped	—	—	—	Quadratic—U-shaped	—	Quadratic—U-shaped	—
Czechia	Linear increase	Linear increase	Quadratic—inverted U-shaped	—	Quadratic—U-shaped*	Linear increase	Cubic*	—
Denmark a	Linear increase	Linear increase	Linear increase	Linear increase	Cubic*	Linear increase	Cubic*	Linear increase
England b	Linear increase	Cubic	Linear increase	—	Cubic*	Quadratic—U-shaped*	Cubic*	Cubic*
Estonia a	Cubic	—	Cubic	—	Cubic	Cubic*	Cubic	Cubic*
Finland a	Quadratic—U-shaped	—	Linear increase	Linear increase	Quadratic—U-shaped	Linear increase*	Cubic*	—*
France a	Quadratic—U-shaped	Quadratic—U-shaped	Quadratic—inverted U-shaped	Cubic	Quadratic—U-shaped	Quadratic—U-shaped	Cubic*	Linear increase*

Germany a	Quadratic—U-shaped	—	Linear increase	—	Cubic*	Cubic*	Quadratic—U-shaped	Linear increase*
Greece b	Cubic	Linear decrease	—	—	Cubic	Cubic*	Cubic*	Quadratic—U-shaped*
Greenland a	Linear increase	—	Linear increase	Linear increase	Linear increase	Linear increase*	Linear increase	Linear increase
Hungary a	Cubic	—	Linear increase	Linear increase	Cubic	Quadratic—U-shaped*	Cubic*	Linear increase
Iceland d	Linear increase	—	Cubic	—	Quadratic—U-shaped*	Quadratic—U-shaped*	Quadratic—U-shaped*	/
Ireland b	Linear increase	—	Linear increase	—	Quadratic—U-shaped*	Quadratic—U-shaped*	Linear increase	Linear increase*
Israel a	—	Linear decrease	—	—	Cubic*	—*	Cubic*	Quadratic–inverted U-shaped*
Italy c	Linear increase	—	Linear increase	—	Quadratic—U-shaped*	Linear increase*	Linear increase	/
Latvia a	Linear increase	Linear increase	Linear increase	Linear increase	Cubic*	Quadratic—U-shaped*	Quadratic—U-shaped*	Linear increase
Lithuania a	Cubic	—	—	Quadratic—inverted U-shaped	Cubic	Cubic*	Cubic*	Quadratic-inverted U-shaped
Luxembourg d	Cubic	—	—	—	Quadratic—U-shaped*	Linear increase*	—	—
North Macedonia c	Quadratic—U-shaped	—	—	—	Quadratic—U-shaped	Linear increase*	Linear increase*	Linear increase*
Malta c	Linear increase	—	Linear increase	Linear increase	Linear increase	—	Linear increase	Linear increase
Netherlands c	Linear increase	—	Cubic	—	Quadratic—U-shaped*	Quadratic—U-shaped*	Linear increase	Linear increase*
Norway a	Linear increase	—	—	—	Linear increase	Cubic*	Linear increase	—
Poland a	Cubic	Cubic	Linear increase	Quadratic—inverted U-shaped	Cubic	Cubic	Cubic*	Linear increase*
Portugal b	Quadratic—U-shaped	Quadratic—U-shaped	—	—	Quadratic—U-shaped	Quadratic—U-shaped	Quadratic—U-shaped*	/
Romania d	Quadratic—U-shaped	—/	—	—	Quadratic—U-shaped	Quadratic—U-shaped*	Cubic*	/
Russia a	—	—	Linear increase	Quadratic—inverted U-shaped	—	—	—	—
Scotland a	Quadratic—U-shaped	Quadratic—U-shaped	Quadratic—U-shaped	—	Quadratic—U-shaped	Quadratic—U-shaped	Quadratic—U-shaped*	Linear increase*

Slovakia a	—	Linear increase	Linear increase	Linear increase	Cubic*	Cubic*	Quadratic—U-shaped*	Linear increase
Slovenia c	Cubic	Quadratic—U-shaped	Linear increase	—	Cubic	Quadratic—U-shaped	Linear increase	Linear increase*
Spain c	Linear decrease	Linear decrease	Linear decrease	—	Quadratic—U-shaped*	Linear decrease	Linear decrease	—
Sweden a	Linear increase	Linear increase	Linear increase	—	Cubic*	Cubic*	Cubic*	Linear increase*
Switzerland b	Quadratic—U-shaped	—	Linear increase	—	Cubic*	Linear increase*	Cubic*	Linear increase*
Ukraine c	Cubic	Quadratic—U-shaped	—	Cubic	—	—	—	—
USA b	Cubic	Linear decrease	—	—	—	—	—	—
Wales a	Quadratic—U-shaped	Cubic	Linear increase	—	Quadratic—U-shaped	Quadratic—U-shaped*	Cubic*	Quadratic—U-shaped*

* = Different trajectory for 1994–2018 versus 1994–2022;
a Data since 1994.
b Data since 1998.
c Data since 2002.
d Data since 2006.
e Data since 2010.

Gender-specific divergences in trajectories were also apparent. Among males, linear rises (32.9%, k = 27) or stable patterns (23.2%, k = 19) predominated, whereas females more frequently exhibited cubic (41.5%, k = 34) or U-shaped (35.4%, k = 29) forms. Thus, female trajectories displayed greater volatility within countries. Symptom-category differences were likewise notable. Psychological symptoms most commonly followed U-shaped (41.5%, k = 34) or cubic (34.1%, k = 28) paths, while somatic symptoms primarily showed linear rises (35.4%, k = 29), followed by cubic (23.2%, k = 19) and stable (20.7%, k = 17) patterns. Among males, psychological symptoms often displayed non-monotonic forms—U-shaped in 15 countries, cubic in 10—versus linear rises in 8. Somatic symptoms in males chiefly followed linear increases (19 countries), with U-shaped (2 countries) and cubic (3 countries) less common. For females, psychological symptoms predominantly showed U-shaped (18 countries) or cubic (16 countries) trajectories, with linear rises in 4. Somatic symptoms in females were most often cubic (16 countries), then U-shaped (11 countries), with linear increases in 10 countries.

Sensitivity testing

Supplementary checks examining alternative thresholds (at least one, two, or three symptoms occurring more than weekly) on the aggregated dataset yielded comparable outcomes across thresholds for males and females, as well as both symptom categories

Given the potential substantial influence of COVID-19 on the most recent wave [30], additional analyses were conducted excluding 2022 data. **Table 3** provides a comparative summary of trajectory results incorporating 2022 data versus the sensitivity exclusion. Removal of 2022 observations altered initial trajectories in multiple nations, underscoring probable COVID-19 effects on long-term patterns.

Among the 38 nations eligible for psychological symptom sensitivity analysis, trajectory shifts occurred in 26 nations for males and 18 for females. For males, inclusion of 2022 data most frequently transformed pre-2018 stability into linear rises (k = 6), U-shaped patterns (k = 6), or cubic forms (k = 5). For females, the predominant shift involved pre-2018 linear rises evolving into more intricate U-shaped (k = 5) or cubic (k = 5) trajectories upon adding 2022 data.

For somatic symptoms, exclusion versus inclusion of 2022 data modified trajectories in 20 nations for males and 28 for females. Among males, adding 2022 data commonly generated linear rises (k = 9) where prior

stability predominated. Among females—mirroring psychological findings—pre-2018 linear rises often converted to cubic patterns (k = 9) with 2022 inclusion. Furthermore, five nations exhibiting pre-2018 stability shifted to cubic trajectories upon incorporating 2022 observations.

The present investigation—encompassing nearly three decades (1994–2022) across 41 nations—sought to determine the optimal temporal trajectories (linear, quadratic, cubic) for psychological and somatic symptoms in representative groups of 15-year-old adolescents, while also assessing gender-specific variations.

Across most nations, both symptom types displayed rising prevalence from 1994 onward, manifesting as consistent escalation (linear), initial decline succeeded by resurgence (U-shaped), or repeated oscillations ending in recent elevation (cubic). Stability or reduction characterised only a minority of cases. Additionally, female trajectories demonstrated greater intricacy, featuring more frequent U-shaped and cubic forms, whereas male patterns—especially for somatic symptoms—tended toward linearity. Such complexity implies amplified volatility, potentially associated with disproportionate female exposure to academic pressure, body dissatisfaction, overweight concerns, and victimisation [24, 31].

Relative to earlier work spanning 1994–2010 [25], trajectory distributions have evolved. Ottová-Jordan *et al*. [25] reported roughly balanced stable, rising (linear/U-shaped), and falling (linear/inverted U-shaped) patterns, with cubic instability in merely four nations. By contrast, the current analysis documents the dominance of upward trajectories into the 2020s. Incorporating 2022 data accentuated recent acceleration and non-monotonic prevalence, aligning with prior observations. While COVID-19 likely contributed, the scarcity of 2018 declines and abundance of pre-pandemic rises versus Ottová-Jordan [25] indicate an established concerning escalation beforehand. Ongoing surveillance is thus essential to discern whether pandemic effects prove transient or perpetuate this worrisome trajectory.

Marked divergences also emerged between psychological and somatic symptom trajectories: psychological often entailed intricate oscillations, whereas somatic followed comparatively steady paths. Extensive multinational heterogeneity characterised patterns by gender and symptom type, without evident regional clustering. These outcomes suggest linear modelling frequently inadequately represents three-decade complexities, notably among females and for psychological symptoms.

Prior evidence has consistently documented greater psychological and somatic symptom prevalence in females versus males, alongside steeper female rises—possibly underlying observed female trajectory intricacy [32, 33]. Certain nations exhibited exceptionally elevated rates: Italy and Israel across both categories, and Greece, particularly for psychological. Macro-structural shifts may partly account for this; for example, ongoing conflict, economic volatility, and violence in Israel impair adolescent mental health [34, 35]; refugee influx and austerity in Greece exacerbate inequities and psychological burden [36, 37]; severe pandemic disruption, extended school shutdowns, academic demands, and digital media exposure in Italy elevate adolescent psychosomatic burden [38, 39].

The supplementary analyses verified that trajectories grew more intricate for males and females alike upon incorporating 2022 observations (post-COVID era). Among males in numerous nations, pre-2018 patterns indicated stability, which transitioned to rising forms with 2022 inclusion. Among females, pre-existing linear escalations frequently evolved into more elaborate configurations when 2022 data were added. These checks revealed intensification of an already-established upward trajectory in females, while signalling the onset of escalation in males.

Apart from the recent elevation in psychological and somatic symptoms—possibly linked to COVID-19—several pronounced oscillations have occurred across the period. Although not examined in depth here, diverse multinational events and societal shifts likely influenced the documented rises in adolescent symptoms. For instance, the 2008 financial downturn has been tied to detrimental impacts on youth mental health [40]. Moreover, issues like environmental degradation [41, 42] and warfare [35, 43] could have driven recent symptom increases.

Societal transformations have also been influential, yielding mixed outcomes for adolescent mental health. The proliferation of internet access from the 1990s and social platforms from the mid-2000s onward probably exerted adverse effects [24, 44], though certain investigations indicate neutral or beneficial influences [45, 46]. Heightened public recognition of mental health concerns, alongside expanded service provision and preventive measures, may have yielded favourable

results [47–51]. National-specific incidents and personal circumstances likely shaped these trajectories as well. Collectively, these—and undoubtedly additional—elements probably account for the noted trajectory diversity. However, attributing specific oscillations to them falls outside this investigation's main focus, rendering causal links speculative.

Strengths, limitations, and future research

A key advantage of this work lies in leveraging repeated cross-sectional HBSC datasets from an extensive multinational sample, maintained via consistent methodology. This enabled a rare exploration of 30-year trajectories across numerous nations, deepening insights into adolescent health dynamics. Nonetheless, certain constraints warrant attention. The HBSC network's swift growth over recent decades resulted in uneven data coverage, with several nations absent from early waves starting in 1994, constraining full trajectory assessment. Self-reported instruments also risk bias, as growing mental health literacy might elevate reported rates, consistent with prevalence inflation ideas [50]. While 15-year-olds display peak symptom levels, incorporating broader age bands in forthcoming work could offer fuller developmental perspectives. Additionally, divergent psychological versus somatic trajectories in most nations prompt queries on their interrelation across time, meriting dedicated future inquiry. Subsequent analyses might cluster nations and integrate macro-indicators—like cultural attributes or welfare/healthcare features—for deeper scrutiny. Finally, the Multiple Health Complaints Scale's emphasis on internalising symptoms may skew gender contrasts. Developmentally, females tend toward internalising, males toward externalising [5]; thus, such tools might underrepresent male distress, necessitating cautious interpretation.

Conclusion

Overall, recent years reveal a multinational escalation in adolescent psychological and somatic symptoms. Non-monotonic trajectories appear more commonly among females than males, and in psychological relative to somatic domains. Dominant forms encompass U-shaped and cubic configurations alongside linear rises. Yet substantial inter-nation heterogeneity characterises these patterns. Such variability emphasises temporal intricacy, implying linear frameworks alone may inadequately encompass three-decade developments.

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